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PROGRESS REPORT

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AN INVESTIGATION OF THE SOLAR CYCLE RESPONSE OF ODD-NITROGEN IN THE THERMOSPHERE

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ABSTRACT

This annual report covers the first year of funding for the study of the solar cycle variations of odd-nitrogen ($N(^2D)$, $N(^4S)$, NO) in the Earth's thermosphere. The study uses the extensive data base generated by the Atmosphere Explorer satellites, and the Solar Mesosphere Explorer Satellite. The AE data are being used, for the first time, to define the solar variability effect on the odd-nitrogen species through analysis of the emission at 520 nm from $N(^2D)$ and the emission from $O^+(^2P)$. Additional AE neutral and ion density data are used to help define and quantify the physical processes controlling the variations. The results from the airglow study will be used in the next two years of this study to explain the solar cycle changes in NO measured by the Solar Mesosphere Explorer.

DATA SETS BEING USED

A. Atmosphere Explorer-C, and E United Abstract Files.

B. Atmosphere Explorer-C, and E, 520 nm and 732 nm airglow data from the Visible Airglow Experiment (VAE).

C. Solar Mesosphere Explorer Nitric Oxide Data

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INTRODUCTION

This report covers the first year of a three year study of the solar cycle variation of odd-nitrogen compounds ($N(^2D)$, $N(^4S)$, and NO) in the Earth's thermosphere. The study will relies heavily on airglow and composition data taken by the Atmosphere Explorer Satellites C, and E, and on the nitric oxide data base derived from Solar Mesosphere Explorer measurements. The solar control of thermospheric odd-nitrogen is an outstanding example of solar-terrestial coupling.

In addition, we have a complete set of data reduction software for this instrument that has been tailored for VAX/VMS computers. Most of this software was developed by co-investigator Solomon, and hence the necessary expertise exists at LASP.

DATA ANALYSIS

Of particular importance to the proposed investigation are the altitude profiles of NO and $N(^2D)$ which are remotely sensed by the AE spacecraft. NO profiles are recovered from resonance florescence in the gamma bands, and $N(^2D)$ is measured from observation of the $^2D -^2 P$ doublet at 520 nm. We have several methods for recovering altitude profiles of the emission rate, including the Abel inversion technique [Roble and Hays, 1972; Solomon and Abreu, 1989] which is applicable to areas of the dayglow that exhibit approximate spherical symmetry, and the tomographic inversion algorithm of Solomon et al. [1984] which may be used to recover two dimensional slices of the emitting region. The Abel inversion is particularly applicable to elliptical orbits during the daytime, where the altitude change of the satellite is used to scan the limb. For circular orbits, the spinning motion of the satellite is used to scan the limb, and either the Abel or tomographic method used to recover the emission rate profile.

An example of an inversion of VAE data taken at 520 nm is shown in Figures 1-3. In Figure 1 we display 10 profiles of 520 nm data from consecutive spins of the satellite on AE-E orbit 10393 for a solar zenith angle of about 35 degrees and a satellite altitude of 276 km. The log of the measured radiance is plotted as a function of altitude. The data below 225 km is from Rayleigh scattering by the atmosphere

and must be subtracted from the profils. Above 225 km the data consists of both a decreasing contribution from the background and the contribution from the 520 nm airglow from excited nitrogen. The dashed line is a linear fit to the log of the radiance data below 200 km.

In Figure 2 we show the results of the subtraction of the fitted background curve from the data above 225 km. The +'s are the data points from the 10 profiles, the solid curve is a cubic fit to the data. The cubic fits the data with sufficient accuracy to allow it to be used in the inversion process. The scatter in the data points is what is expected from the instrument counting rates for this emission.

The Abel inversion technique is then used to obtain the volume emission rate profile from the fitted limb scan measurements. This inversion method assumes that local horizontal variations in the emission function are negligible, and that the instrument line-of-sight traverses the entire emission region. Since for the high altitude 520 nm emission layer, the satellite is typically at an altitude where there is still significant emission, a correction must be made to account for the portion of the emission that the instrument does not directly observe. This is accomplished by calculating the brightness above the satellite orbit (at zenith angle $\zeta < 90$ deg), reflecting that profile about the horizontal, and adding it to the fitted limb scan. Figure 3 shows an example of this, where the doted line is the original fit and the solid line is the corrected fit. Here, the brightness profile above the orbit is estimated using the Chapman grazing-integral function applied to the horizontal column brightness at $\zeta = 90$ deg, but in the future this correction will be made using the actual measurements for $\zeta < 90$ deg. The corrected profile is then inverted.

The results are shown in Figure 4 as volume emission rate as a function of altitude. The maximum emission rate occurs at about 260 km with an intensity of 4.5 photons/cm^3/s. The precision and accuracy of the data are adequate to reveal the expected solar cycle changes of a factor of 2 or more.

EFFORT

During the second year, the data will be reduced and analyzed using the model

to define the physical processes responsible for the variations in $N(^2D)$ and $N(^4S)$. During the final year, this analysis will continue and the NO data from the SME will be analyzed in light of the new understanding of the processes controlling the odd-nitrogen densities and changes. Comparisons will also be made to the NCAR TIGCM.

MANAGEMENT DESCRIPTION

The principal investigator, D.W. Rusch, continues to assume the major responsibility for the completion of the project. In particular, Rusch is responsible for overseeing the budget and directing all facets of the research. He is responsible for the integrity of the data, the establishment of the data base, for directing the inversion and modeling efforts, and is jointly responsible for the publication of results.

Co-investigator, S. C. Solomon, is primarily responsible for the inversion of the AE data, and jointly responsible with the P.I. for the modeling effort and publication of results.

REFERENCES

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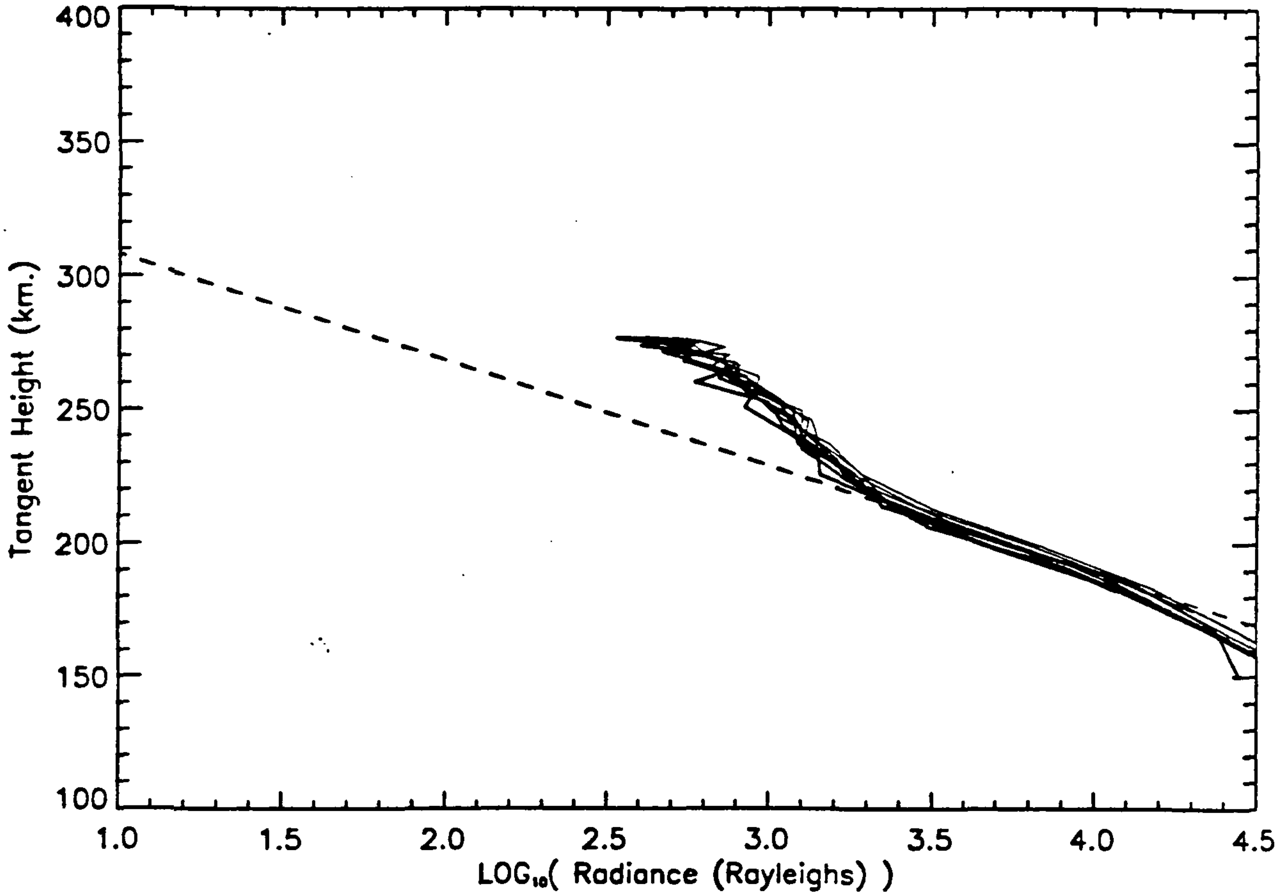

Figure 1. 520 nm radiance as a function of altitude with background for 10 consecutive spins. The dashed line is the fit to the scattered light below 200 km.

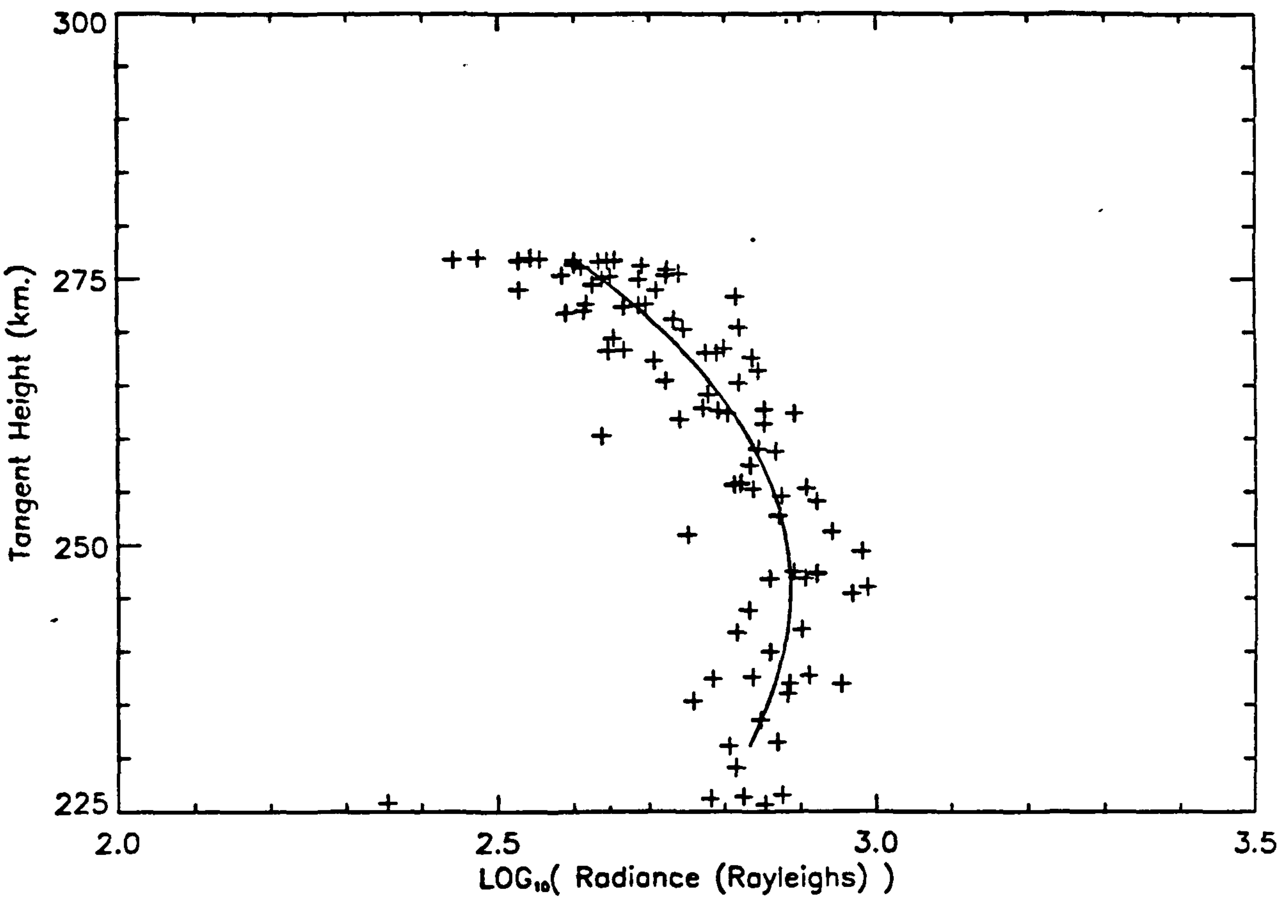

Figure 2. The altitude profile of 520 nm column emission after the background subtraction. The +'s are the data. The solid line is the fitted cubic polynomial.

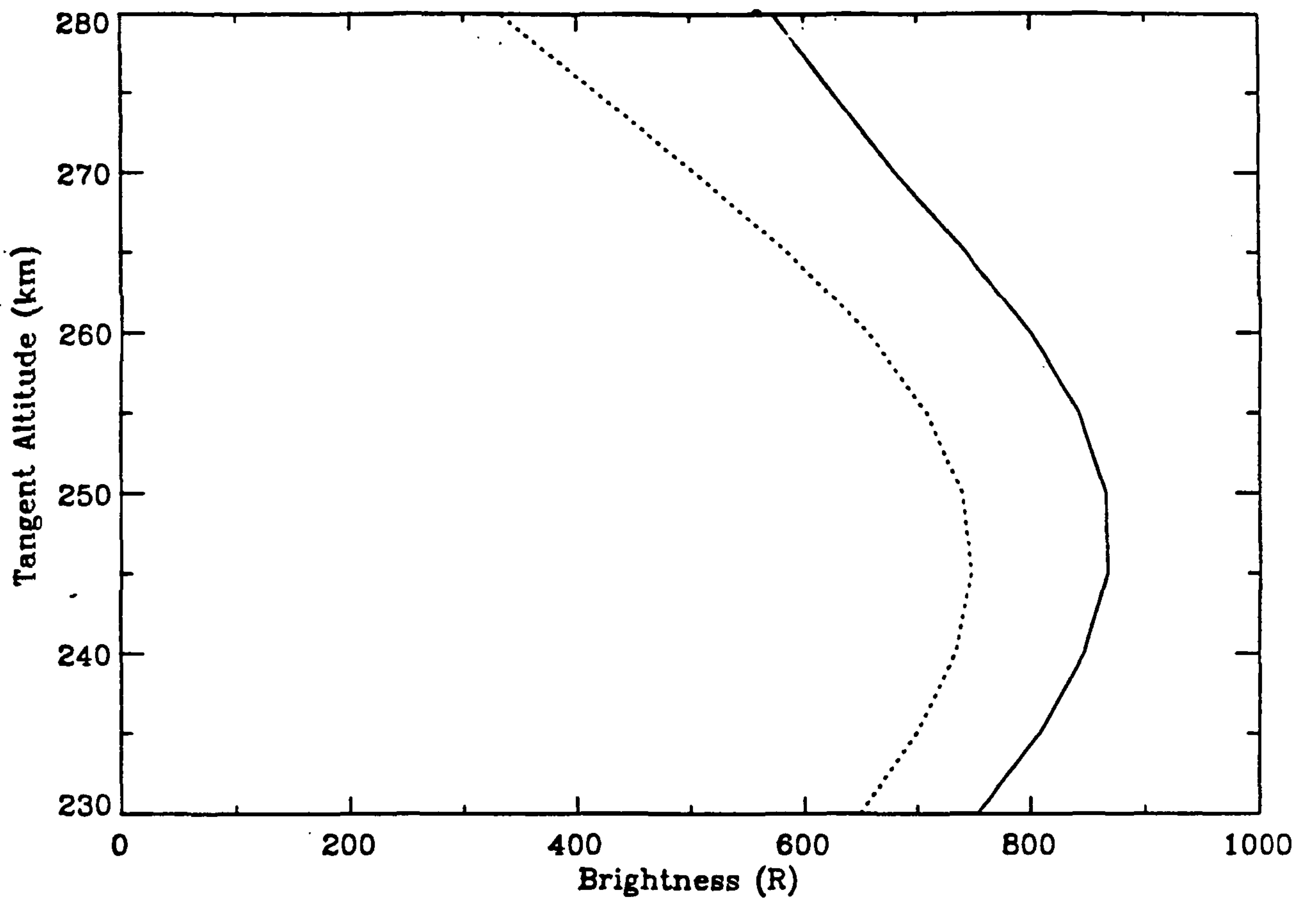

Figure 3. 520 nm brightness as a function of altitude. The dashed line is the fit from Figure 2. The solid line is the corrected profile as described in the text.

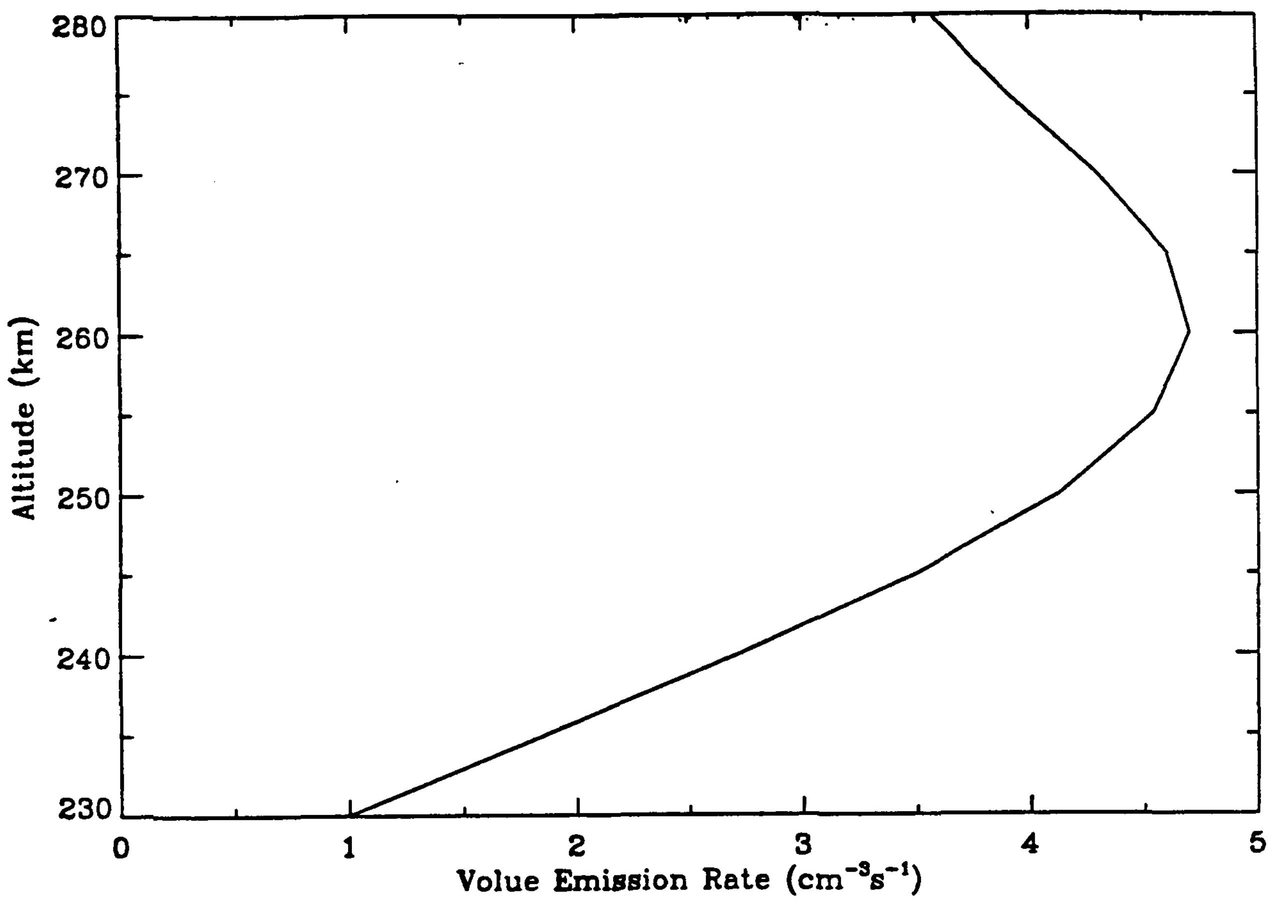

Figure 4. 520 nm volume emission rate as a function of altitude resulting from the inversion of the emission rate shown in Figure 3.